Section 2. EOS Program Overview

The overall goal of the EOS mission is to advance the scientific understanding of the entire Earth system on a global scale by developing a greater understanding of the geophysical parameters of the Earth system, the interactions among them, and the way the Earth is changing.

The EOS program mission objectives are as follows:

- To create an integrated scientific observing system emphasizing climate change, causes, processes, and effects that will enable multidisciplinary study of the Earth's critical, life-enabling, interrelated processes involving the atmosphere, oceans, land surface, polar regions, and solid Earth, and the dynamic and energetic interactions among them.

- To develop a comprehensive data and information system, including a data retrieval and processing system, to serve the needs of scientists performing an integrated multidisciplinary study of planet Earth.

- To acquire and assemble a global database of remote sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes. The EOS program provides the science user community with data and the supporting information system necessary to develop a comprehensive understanding of the way the Earth functions as a global system.

The three primary components of the EOS program and their purposes are as follows:

1) **The EOS Space System**—to acquire essential global Earth science data on a long-term sustained basis and in a manner that maximizes the scientific utility of the data and simplifies data analysis.

2) **The Integrated Scientific Research Program**—to investigate processes in the Earth System and improve predictive models.

3) **The EOS Ground System**—to provide the Earth science research community with easy, affordable, and reliable access to the full suite of Earth science data from U.S. and IP platforms.

Figure 2-1 shows the relationship of these EOS components.

2.1 EOS Space System

The EOS Flight and Observing System consists of a series of predominantly polar-orbiting spacecraft. The United States, the European Space Agency (ESA) and Japan's National Space Development Agency (NASDA) are scheduled to fly EOS missions. Table 2-1 summarizes the EOS-era missions currently planned.

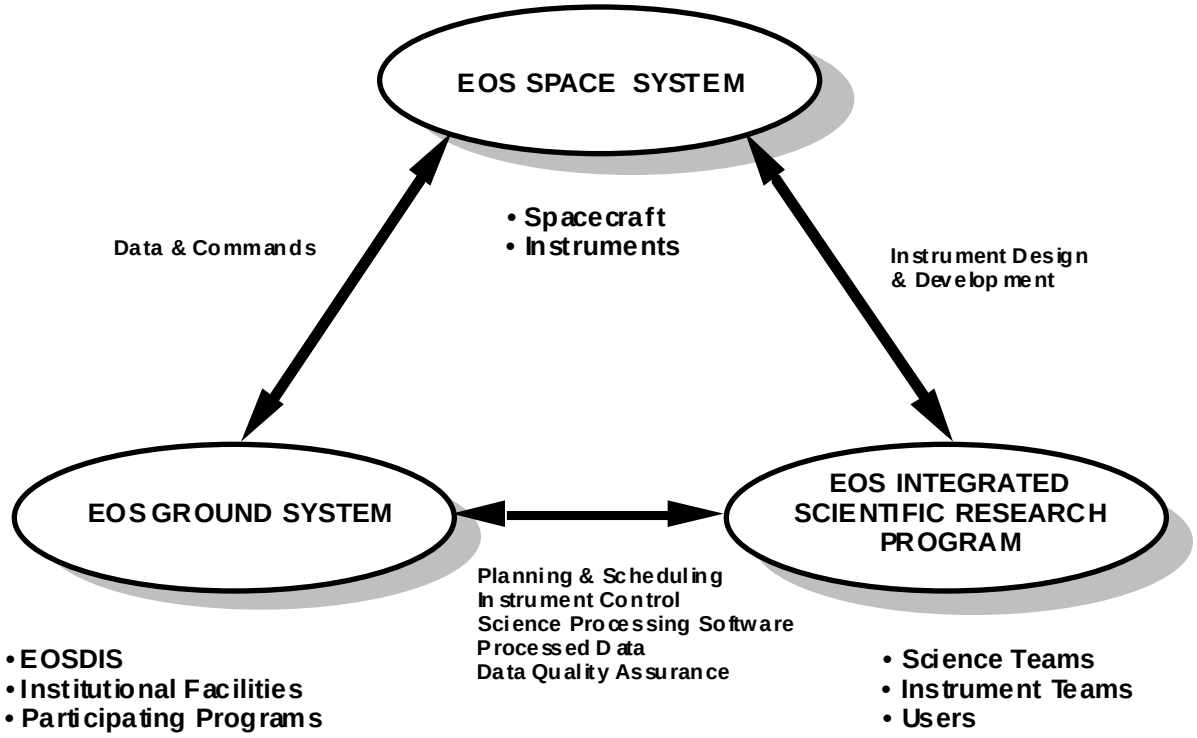

Figure 2-1. Major EOS Segments

Table 2.-1. Planned EOS-Era Missions

Country	Program	Spacecraft	Launches (Tentative)
United States	Earth Observing System (EOS)	AM series	1998, 2004
		PM series	2000, 2006
		LALT series	2002, 2007
		CHEM series	2002, 2008, 2008
ESA	Polar-Orbit Earth Observation Mission (POEM)	ENVISAT series	1998
		METOP series	2000
Japan	Japanese Earth Observing System (JEOS)	ADEOS IIA	1999
		ADEOS IIB	to be scheduled
		TRMM-2	2000

Four series of U.S. EOS spacecraft are planned, each with a different flight configuration based on scientific measurement objectives. During EOS's projected 20-year operational lifetime, as many as four spacecraft (one from each series) may be operating simultaneously. In addition, two

spacecraft from the same series may be in orbit during a spacecraft crossover replacement period of up to 6 months. The *Execution Phase Project Plan for Earth Observing System (EOS)* and the documentation associated with each mission provide more detailed information about each series.

The scientific instruments for the NASA EOS spacecraft are divided into two classes, facility instrument and principal investigator (PI) instrument. Facility instruments measure variables useful to a wide range of science disciplines; PI instruments observe more specific phenomena. Many instruments have been selected or are in the process of being selected to be flown on the U.S. EOS series of spacecraft. In addition to these EOS spacecraft, EOS-funded Flight of Opportunity (FOO) instruments will be flown on other U.S. and international spacecraft. For details about the EOS instruments, see the *EOS Reference Handbook.*

The AM-1 spacecraft will use the Space Network (SN) Tracking and Data Relay Satellite System (TDRSS) as its initial space-to-ground communications link. It will also have an X-band capability that will be used in the event of a failure in the primary downlink communications path. For all subsequent NASA EOS spacecraft, the primary communications link will be an X-band downlink to dedicated EOSDIS ground stations. The X-band sites will also provide S-band command and control links, although all EOS spacecraft will retain capabilities for using the SN for command and control. The AM-1 spacecraft may change to X-band site support also. All EOS spacecraft may utilize the Deep Space Network (DSN), Ground Network (GN), and Wallops Orbital Tracking Station (WOTS) for emergency communications.

2.2 Integrated Scientific Research Program

The Integrated Scientific Research Program focuses on the utilization of EOS data. It includes funding for postgraduate fellowships in the area of global change, for interdisciplinary investigators (IIs) performing integrated studies of the Earth to enhance the capability to predict global change, and instrument investigations to focus on the development of and utilization of data from particular instruments.

The Integrated Scientific Research Program is led by the science/user community. The scientists determine the observations to be made. The PIs and Co-Investigators (Co-Is) help the instrument engineering teams build the instruments required to collect the data. The science teams plan and schedule the use of the instruments. The scientists provide science algorithms for generating data products and performing quality assurance on the generated products. They also analyze the data from the EOS instruments, publish the results, and make recommendations for the global change research community.

The other EOS investigators supported by the research program include research facility instrument Team Members (TMs), led by their Team Leaders (TLs), who make use of the facility instruments being developed by the EOS project; and the IIs, who are interested in the analysis and interpretations of data from EOS instruments and related data from other sources.

2.2.1 Science Objectives

The science objectives determine the EOS missions and science instruments to be flown on these missions. Most of the science instruments are developed by and are the responsibility of NASA

centers, such as Jet Propulsion Laboratory (JPL), Langley Research Center (LaRC), and Goddard Space Flight Center (GSFC). These centers, in many cases, also house the PI and the Distributed Active Archive Centers (DAACs) responsible for these instruments. DAACs will process, archive, and distribute science data to the user community. EOSDIS builds on existing discipline-specific Earth science data centers and data systems. NASA initially selected eight DAACs to carry out the responsibilities for EOSDIS data management. These assignments were based primarily on the current distribution of expertise and activities.

Table 2-2 shows the major science objectives for each series. More information on science objectives is available in the EOS Reference Handbook and on the World Wide Web.

Table 2-2. Summary of EOS Science Objectives

Series	Major Science Objectives
AM	Characterization of the terrestrial and oceanic surfaces
	Clouds, aerosols, and radiation
	Radiative balance
	Sources and sinks of greenhouse gases
PM	Cloud formation, precipitation, and radiative balance
	Terrestrial snow and sea ice
	Sea-surface temperature and ocean productivity
LALT	Ice sheet mass balance
CHEM	Atmospheric chemical species and their transformations

2.2.2 User Community

The EOS user community includes PI/TLs/TMs, the IIs, the international science users, and the general science users. Social scientists have collaborative access through the Socio-Economic Data Applications Center (SEDAC) DAAC, and educational organizations represent a large segment of the intended user population. The reader is referred to the web sites listed in Section 1.4 for further explicit information on these topics.

2.2.2.1 Principal Investigators, Team Leaders, and Team Members

There are major perspectives within the user community, such as instrument-oriented users and discipline-oriented users. An instrument-oriented user is concerned with how to best use the data from a given instrument to learn more about the environment. This user is particularly interested in how to best calibrate the instrument and validate its data products; this user is also interested in developing new sensing techniques. The discipline-oriented user is usually a PI or Co-I associated with an interdisciplinary science team. Their interest is likely to involve use of data from multiple instruments to tackle a science problem.

Within the user community, there is a further distinction between investigators interested in global data sets and investigators oriented towards regional data. The two geographic interests are

important for such data operations as subsetting and data examination. A global investigator is likely to want overviews and latitudinal averages as part of his searches for meaningful data. A regional investigator is likely to want to look at small portions of the Earth with many different kinds of data. The investigator needs subsets of many of the standard data products. Design of EOSDIS accommodates the discipline-oriented investigators' requirement for global modeling. This activity requires a large number of diverse inputs, and large volumes of data are generated by running the model.

Instrument investigations are performed by a group of scientists responsible for the design, development, test, calibration, operation, algorithm development, and data analysis for Earth observing instruments. These scientists, under the leadership of the PI, plan and conduct research; reduce, analyze, and interpret data; and publish their results. The PI ensures that the experiment definition; instrument design and development; planning and support of mission operations; and data validation, quality control, analysis, and publication are successfully carried out. The Co-Is assist the PI in meeting his/her responsibilities and participate in the group's operation as defined in a Science Management Plan.

A Facility Instrument Team consists of selected scientists who can contribute substantially to guiding the design, development, test, calibration, operation, data reduction, or algorithm development of a facility instrument. The Facility Instrument TMs function in a manner similar to the Co-Is on an instrument investigation. Each team is organized under the direction of a TL. The TL has primary responsibility for conducting the team's investigation as well as directing team activities.

The PIs and/or the Instrument Team Leaders perform a special role within the user community. They utilize the SCFs, where new algorithms are developed and updated, special data sets are produced, and data quality checking is performed. The Instrument Working Group and the Project Scientist provide long-term science plans; PIs and TLs contribute to this effort.

2.2.2.2 Interdisciplinary Investigators

IIs are a group of scientists interested in the analysis and interpretation of data from EOS instruments as well as data from other sources. This participation is intended to exploit the synergistic nature of the EOS experiments so that the multidisciplinary scientific tasks of EOS are adequately addressed, to help guide the development of EOSDIS, and to provide a strong theory and data analysis perspective to mission planning. In addition to analyzing data, these investigations may include the development of theoretical models whose capabilities and results will be made available to the EOS investigator community. The IIs, under the leadership of the PI, plan and conduct the research, analyze and interpret EOS and non-EOS data, and publish their results.

The EOS IIs are supportive of two main themes:

1. The Earth System can be subdivided into several components: atmosphere, ocean, land biosphere, fresh water, snow, and ice. State variables associated with these various components can be estimated from measurements with the EOS instruments.

2. The cycles that link various parts of the Earth System can be identified: energy and momentum balance, the hydrologic cycle, the biogeochemical cycle, and ecosystem dynamics. Most of the interdisciplinary investigations address these links between components.

2.2.2.3 International Science Users

The International participants, ESA and Japan, provide data acquisition, processing, archiving, and distribution capabilities in support of their spacecraft, instrument payloads, and satellite communications relay. Each participant has a ground system for data processing and distribution.

These ground systems provide for the exchange of spacecraft and payload data. All agencies exchange data and support planning and scheduling, commanding, and operations of instruments on their respective spacecraft. U.S. spacecraft carry instruments from several countries, requiring commanding support as well as data processing and exchange services. U.S. participants require data from international payloads on any of the spacecraft, and the international participants require access to U.S. payload data for their processing and/or investigations. EOSDIS provides for the exchange of data between the United States and the international databases. A NASA Headquarters Memorandum of Understanding (MOU) defines the interface between the IPs and the EOS program.

ASTER is a facility instrument provided by Japan's MITI under an agreement with NASA. Architecturally similar to ECS in functionality and operational concept, the ASTER Ground Data System (GDS) is composed of three segments : the ASTER Operations Segment (consisting of the ASTER IST and ICC), the Communications and Systems Management Segment (CSMS), and the SDPS.

2.2.2.4 General Users

The user community extends past the boundary of mission-selected research scientists (the PI, Co-I, and TL/TM) associated with a particular instrument or research investigation. EOS data and information is used by the broader operational and research communities, including such groups as U.S. and international operational agencies and the international Earth science research community at academic and government institutions. Researchers at academic and governmental institutions who are not affiliated with the EOS program can access the EOSDIS catalogs and order EOS products. In particular, the EOS data system provides access to data for research programs of other U.S. Government agencies (e.g., the U.S. Geological Survey and the National Forest Service).

2.3 EOS Ground System

2.3.1 EGS Overview

The EGS is an integration of EOS spacecraft ground support, science investigator support, data centers, IP ground stations, user networks, non-EOS ground systems, contractor facilities, NASA institutional support, and EOSDIS. EOSDIS is the dedicated and unique portion of the EGS developed by the ESDIS Project.

EOSDIS, as the NASA overall Earth science discipline data system, provides the ground system for the collection and analysis of science data to support scientists in resolving the dynamics of the Earth's components and the processes by which they interact. As a part of the EOS program, EOSDIS supports the planning, scheduling, and control of the EOS series of spacecraft, exchanging commands, data, and algorithms with ESA, Japan, Canada, the National Oceanic and Atmospheric Administration (NOAA), and any other non-NASA entities involved in the overall EOS mission. EOSDIS is also responsible for coordinating these activities with other data-gathering systems and transforming the observations into physical variables, providing for higher levels of processing, and presenting the data to users in forms that facilitate and stimulate interactive scientific research. EOSDIS supports NASA Earth Probe missions (non-EOS NASA Earth science flight projects) and adds to its database other selected non-EOS data that are required for use in conjunction with EOS data. EOS, Earth Probe, and other selected non-EOS data and products are cataloged, archived, and retrieved in a manner that supports the scientist in developing a better understanding of the way the Earth functions.

Table 2-3 summarizes the major elements of EGS.

Section 3 of this document provides more details on the components that make up the EGS, including design drivers for each component. Figure 2-2 is a Venn diagram of EGS. Included in this diagram are the section numbers in this document where more information can be found on individual systems. Figure 2-3 summarizes the EGS components and interfaces. (See Figure 1-2 for a detailed interface diagram depicting the overall EGS architecture.)

2.3.2 EGS Environment

In general, the EOS AM-1 spacecraft transmits data through the Tracking and Data Relay Satellites (TDRSs), which forward the data to the receiving station at White Sands, New Mexico. From White Sands, the data are transmitted via circuits to GSFC, where these data are processed to recover the raw instrument data. IP satellites downlink directly to the IP Ground Systems via their ground receiving stations. Data from NASA instruments on the IP platforms are transmitted to GSFC via commercial networks. Landsat-7 downlinks data directly to the Landsat-7 Ground Station (LGS) at the EROS Data Center (EDC) and to International Ground Stations (IGSs).

For EOS missions subsequent to AM-1, the science data will be transmitted via high-latitude X-band EOSDIS ground stations in Alaska and Norway. These high-latitude ground stations will then forward the science data to GSFC.

Flight operations (including spacecraft and instruments) are conducted from the EOC. Non-U.S. instruments on U.S. platforms are operated and monitored through IP ICCs.

2.3.2.1 Distributed Active Archive Centers

DAACs were selected on the basis of scientific expertise, experience with data and information systems, and long-term institutional commitment to support the DAAC function for the EOS program.

Table 2-3. Summary of EGS Elements and Their Roles

EGS Element	Role
EOSDIS	
• EOSDIS Core System (ECS)	Provides EOS flight operations; science data processing; and EOSDIS communications and system management
• Distributed Active Archive Centers (DAACs)	Provides production, archive, and distribution of EOS and non-EOS science data products, and user support
• Version 0	Provides a working prototype of selected key EOSDIS services with some operational elements
• Science Computing Facilities (SCFs)	Provides science data processing software/algorithms, data product quality assessment, and user support
• EOS Data and Operations System (EDOS)	Provides EOS data capture, level 0 processing, and backup archive
• EOSDIS Backbone Network (EBnet) and External Network	Provides EGS mission operations communication services and science operations communication services
• EOSDIS Test System (ETS)	Provides test data generation and EGS element simulation capabilities
• EOSDIS Ground Stations	Provide space to ground communications services for post-AM-1 missions
Institutional facilities	
• Flight Dynamics	Provides orbit and attitude data, and orbit adjust and maneuver computations for EOS spacecraft
• Nascom	Provides communications services between the White Sands Complex (WSC) and EGS elements
• Space Network	Provides TDRSS services for AM-1 spacecraft; coordinates other ground station scheduling
• Ground Network (GN), Deep Space Network (DSN), Wallops Orbital Tracking Station (WOTS)	Provide backup low-rate communications services
• X-Band Backup Ground Stations	Provide backup science data communications services for AM-1
Participating Programs	
• EOS Spacecraft Ground Support	Provides real-time spacecraft simulations, generation and test of flight software updates, integration and test facilities, operational launch support services, and spacecraft sustaining engineering facilities and services

• International Partner Facilities	Includes interfaces with international partner facilities such as the ASTER Ground Data System (GDS), and the NASDA Earth Observation Information System (EOIS)
• Affiliated Data Centers (ADCs) & Other Data Centers (ODCs)	Provides selected Earth science data and metadata to DAACs for archive and user access; examples include the Landsat Processing System (LPS), and the TRMM Science Data and Information System (TSDIS), and the NOAA Satellite Active Archive
• User Facilities	Provides user access to EOSDIS science data
• NASA Science Internet (NSI)	Provides external communications services between EOSDIS and EOSDIS users

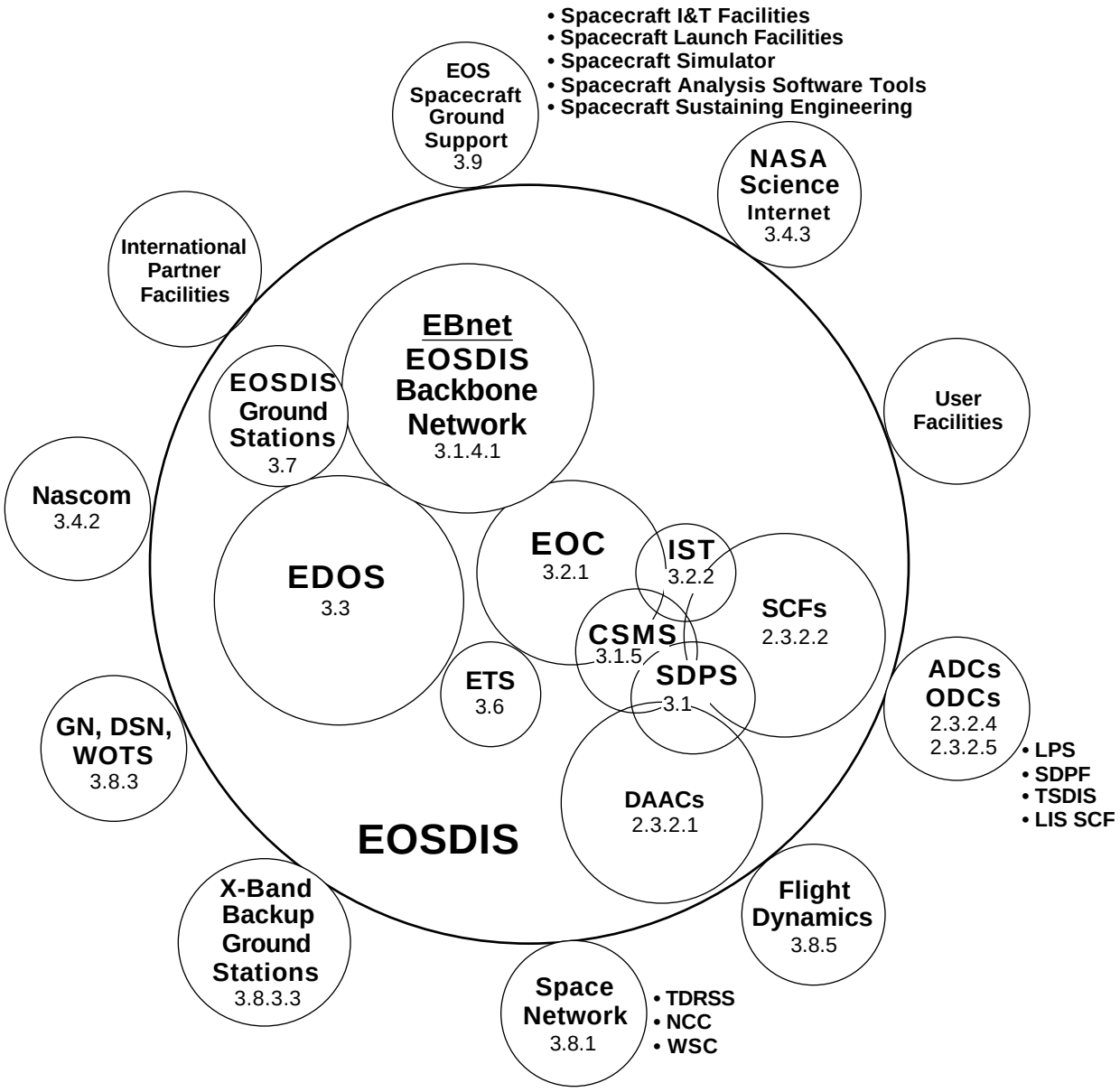

Figure 2-2. Venn Diagram of EOS Ground System

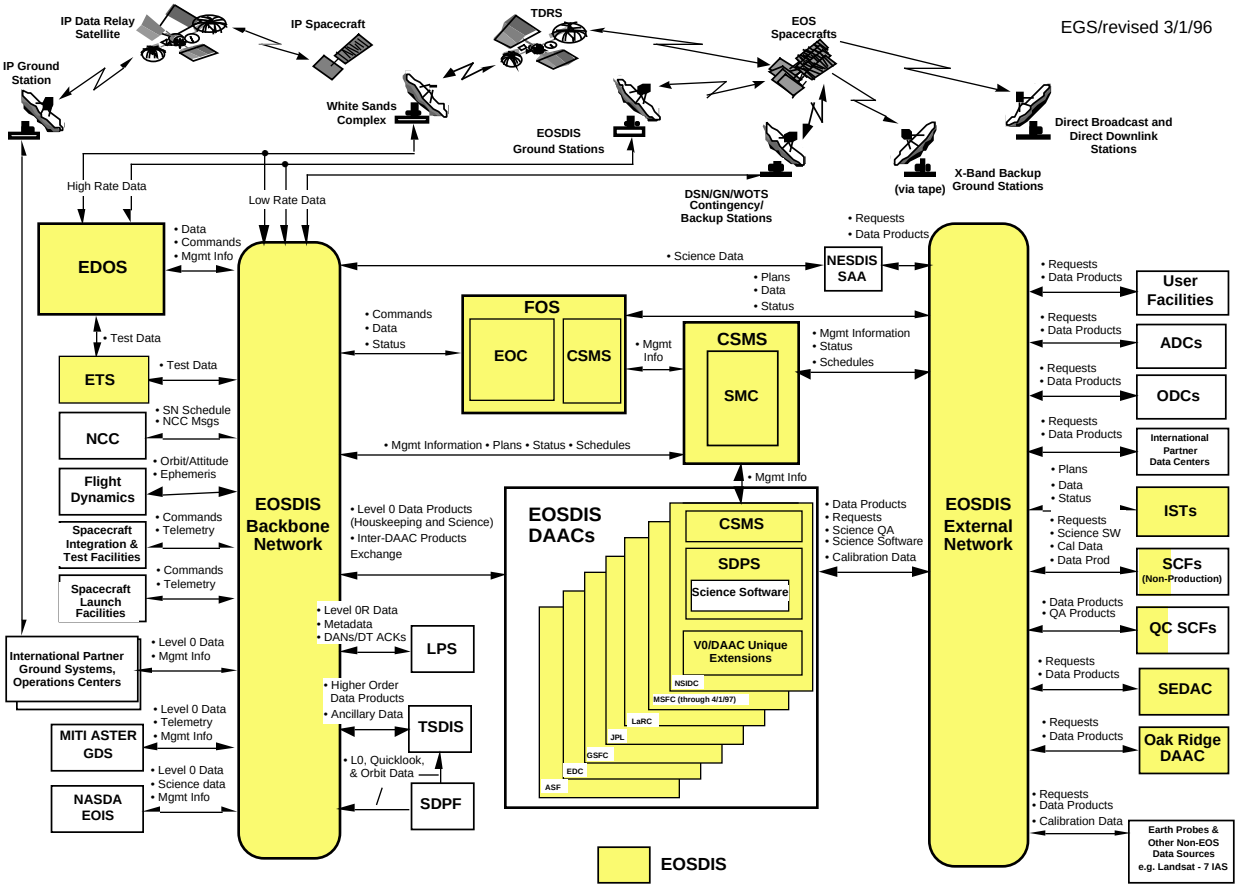

Figure 2-3. EGS Components and Interfaces

Under the general purpose of providing data and information services to users, DAACs have many responsibilities, including the following:

a) Preserve data for users by providing a secure data archive, all needed supporting information, and long-term maintenance. This includes existing NASA data, near-term flight projects, and the EOS mission (all Mission to Planet Earth [MTPE] data). DAAC archive is maintained until data are transferred to long-term archive.

b) Generate products to meet user requirements, using investigators' science software where appropriate.

c) Help users to quickly and easily locate and order data. This includes access to the Global Change Master Directory, tailored services for DAAC-specific discipline users, "one-stop shopping" for all NASA MTPE data for all users, and referrals to other DAACs and other agency data centers.

d) Distribute data to investigators using a common format to facilitate interuse of data sets. Data will be distributed using electronic distribution for rapid response and hard media for bulk requests. Each DAAC will interface with other DAACs for the purpose of routing EOS data products, browse and metadata information, and documentation required for interpretation; and distributing desired information and data products to the requested users.

e) Maintain operational user support offices and documentation of all data sets, including an online guide.

f) Pursue an active, responsive relationship with the User Working Group. (Each DAAC has a working group of users to provide advice on priorities for scientific data, levels of service, and the capabilities needed.)

g) Provide long-term user support for EOS products, even after instrument teams have gone on to other work. The DAAC staff will stay knowledgeable on EOS products to provide effective user support.

Most science users access EOS data products via the shared NSI. Open access to the data by all members of the science community distinguishes the EOS from previous research satellite projects, where selected investigators have had proprietary data rights for a number of years after data acquisition.

Each DAAC has an ongoing Earth science function that is augmented by the added EOSDIS capabilities. Table 2-4 summarizes the EOSDIS DAACs, their respective science disciplines, and the missions and instruments supported.

2.3.2.2 Science Computing Facilities

The SCFs are part of the computer facilities at investigators' institutions that are used for scientific research. The SCFs may range from single workstations to large supercomputer data centers.

The ESDIS Project provides each SCF with a science toolkit to allow communication with the DAACs for data product development and an instrument toolkit for instrument monitoring/control with the EOC. Using these toolkits, the scientists develop and validate their algorithms at the SCF and migrate the algorithms to the DAACs. Instrumenters can also monitor the status of their instruments and conduct performance analysis from the SCF, using the EOC. They may also schedule instrument activities with the EOC.

The primary functions of an SCF include the following:

- Support data production and science software development, including the development and maintenance of algorithms/software for producing data products.
- Support data analysis, visualization, and manipulation required for the scientist’s research
- Perform QC of standard products. (QC SCFs typically have subsets of the capabilities of the other SCFs.)

- Support instrument operations planning and scheduling and instrument performance monitoring and trending.
- Provide interfaces to the scientists' institutional computer facilities.
- Support data set validation, instrument calibration, and behavior analysis.
- Support generation of specialized products and computations required for the scientists' research.

Table 2-4. DAAC Summary

DAAC	Science Discipline Assignments Made	Mission/Platform	Instrument/Experiment
Alaska SAR Facility (University of Alaska - Fairbanks)	Synthetic Aperture Radar Study, Polar Processes	ERS and JERS series RADARSAT	SAR SAR
EROS Data Center (USGS)	Land Processes Imagery	AM-1 Landsat-7	ASTER and MODIS (L2+/land) ETM
Goddard Space Flight Center (NASA)	Upper Atmosphere, Atmospheric Dynamics, Global Biosphere, Geophysics	TRMM SEASTAR ADEOS-I AM and PM series PM series Laser Altimeter CHEM-1 Flight of Opportunity (FOO)	VIRS (a/d) PR (a/d), TMI (a/d), GV (a/d) SeaWiFS TOMS (a/d) MODIS AIRS, AMSU, MHS, AMSR GLAS (LO/1) HIRDLS, MLS SOLSTICE III
Jet Propulsion Laboratory Interaction (Cal Tech)	Ocean Circulation and Air-Sea Interaction	ADEOS-I ADEOS-II Radar-Altimeter	NSCAT (a/d) Seawinds MR, POD, DFA
Langley Research Center Tropospheric (NASA)	Radiation Budget, Aerosols, Chemistry	TRMM AM-1 AM-2 PM series, FOO FOO FOO, Meteor, and Space Station CHEM-1	CERES CERES, MISR, and MOPITT CERES, MISR, EOSP CERES ACRIM SAGE III TES
Marshall Space Flight Center (NASA) (until 4/1/97 only)	Hydrology	TRMM	LIS
National Snow and Ice Data Center (U. of Colorado)	Cryosphere (non-SAR)	AM-1 and PM-1 PM-1 Laser Altimeter	MODIS AMSR GLAS (L2+)
Oak Ridge National Laboratory (DOE)	Biogeochemical Dynamics	None	None

Socio-Economic Data Applications Center (CIESIN)	Policy/Decision Making Applications of Combined MTPE and Socio-Economic Data	None	None

Figure 2-4 provides an overview of the SCF interfaces with the EGS. This figure, and many others throughout this document, is a subset of Figure 1-2; reference to that figure will therefore provide additional context.

2.3.2.3 Data Assimilation Office/Data Assimilation System

The mission of the Data Assimilation Office (DAO) is to advance the state of the art of data assimilation and to use the assimilated data in a wide variety of Earth system problems. Data assimilation is the construction of global data sets that are physically and chemically consistent, from the many data sources in routine operations or from special research projects in a number of disciplines, including weather prediction, oceanography, and atmospheric chemistry. Much of these data come from satellite operations, using accurate calibrated instruments over long periods of time, albeit scattered in space and time. Data assimilation allows the formation of a time sequence of three-dimensional pictures of the Earth system. This work has been recognized as a national priority to assure that maximum information is obtained from the observational systems.

The Data Assimilation System (DAS) is the collection of software, hardware, and operations personnel employed and managed by the DAO to carry out its mission. Important parts of the DAS include the set of assimilation algorithms developed by the DAO, a large collection of dedicated processors and storage equipment to accommodate its workload, and a DAS scheduling facility. DAS is also a substantial user of EOSDIS planning and science processing resources.

2.3.2.4 Affiliated Data Centers

Affiliated Data Centers (ADCs) allow access to non-EOS data sets to satisfy user queries and for use as ancillary data for standard product generation. ADCs share data and results with DAACs, supporting the science objectives of the EOS program. The ADCs include the NOAA National Environmental Satellite Data and Information Service (NESDIS); National Center for Environmental Prediction (NCEP); the University of Wisconsin; and the Incorporated Research Institutions for Seismology (IRIS) Data Center.

NOAA produces many atmospheric and oceanographic data sets and maintains several databases of key importance to the EOS research program. These include both Level 1 and derived geophysical products, some of which are routinely required to support the production or validation of EOS standard products.

Under a NOAA contract, the Space Science and Engineering Center of the University of Wisconsin maintains a long-term archive and distribution function for Level 1 data from NOAA GOES environmental satellites.

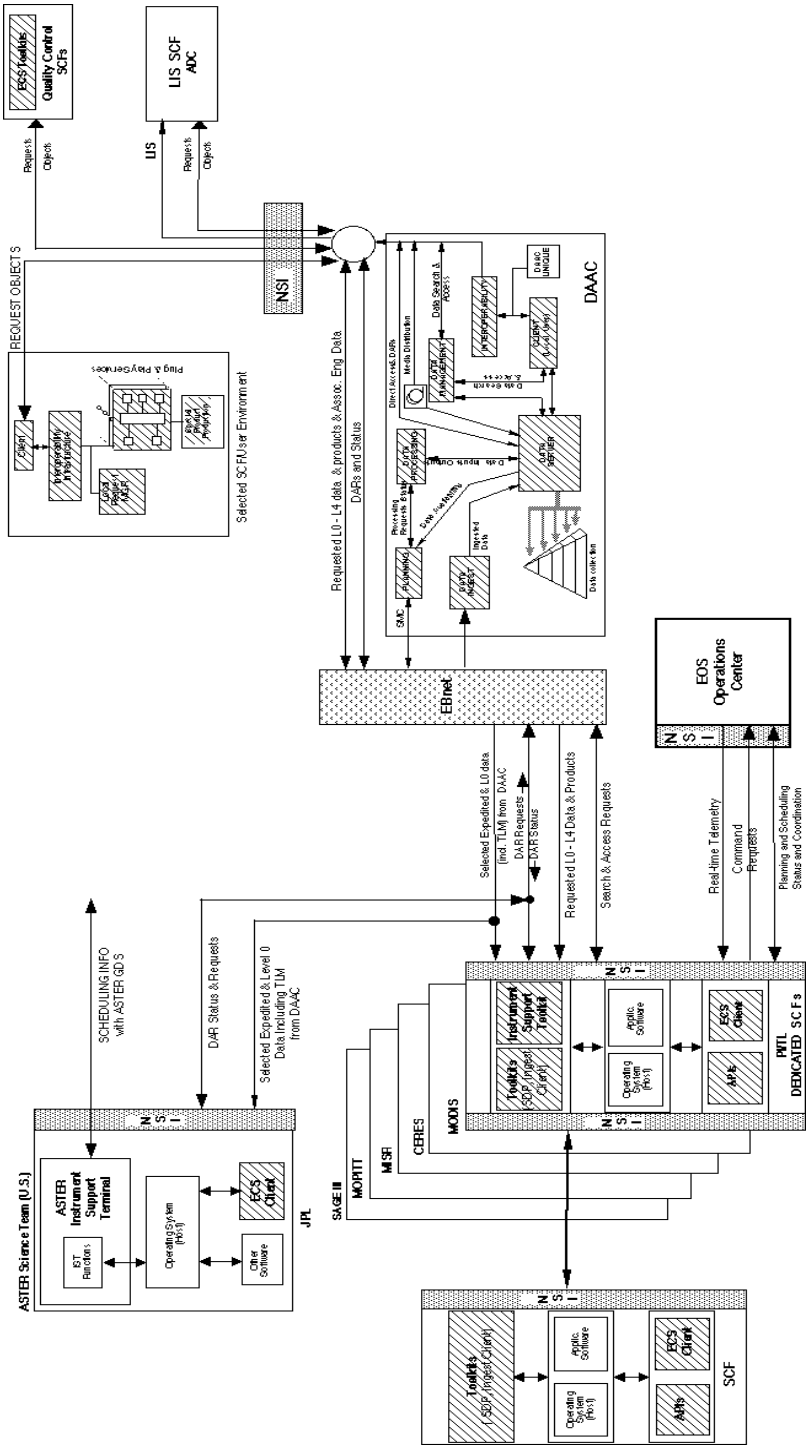

Figure 2-4. SCF Components and Interfaces

NESDIS is responsible for the operation of geostationary and polar orbiting meteorological satellites. NESDIS centers can access EOS data and provide data analyses reports back to the DAACs.

The NCEP and its Climate Analysis Center provide routine weather and climate forecasts for the United States. These are produced by operation of large-scale models that ingest data from a vast array of sources, ranging from ground observations to satellites. The products are of critical importance to the U.S. Global Change Research Program (USGCRP).

The IRIS data center located in Seattle, Washington, receives the Wide Band Data Collection System data from EGS. The National Science Foundation uses these data for analysis and collection of seismic and other scientific data.

2.3.2.5 Other Data Centers

Other Data Centers (ODCs) provide access to data identified by EOSDIS users as required for their research but not available directly within EOSDIS or through ADCs. All ODCs are accessed by EOSDIS through GCDIS. Detailed EOSDIS requirements for ODCs are established as part of the negotiations with the data center. At minimum, each ODC shall be capable of fulfilling the following requirements:

- Provide a single point of access to EOSDIS
- Make its data system available to EOSDIS users
- Provide access to user services